2009 MATE International Competition

Massachusetts

Technical Report

RGU Team

The Robert Gordon University, Aberdeen

Explorer Class

Team Members:

Slimane Kerrouchi, 2nd Year Mechanical & Offshore Engineering
Chris Blackie: 2nd Year Mechanical Engineering
Jack Christie: 2nd Year Mechanical & Energy Engineering
Tom McIntyre: 2nd Year Mechanical Engineering
Barry Mitchell: 3rd Year Electrical Engineering
Sakshi Sircar: 2nd Year Mechanical & Energy Engineering

Mentors:

Graeme Dunbar, Lecturer
John Still, EA Supervisor
Dr Allan Owen, Lecturer

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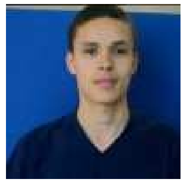
I. Abstract:

The following technical report details the building of an ROV by members of the Robert Gordon University in order to compete in the 2009 MATE International ROV competition. For the current year of competition the main theme centres on submarine inspection and retrieval, and the ROV was designed to be able to carry out various tasks which relate to this topic.

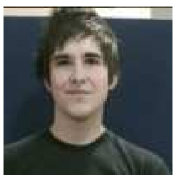
Manufactured on a budget of £1800, the main frame of the ROV is constructed from "L" Aluminium bar joined together by a custom build bracket system. The bracket system is designed in order to maximise the strength in each joint whilst keeping weight and material usage low. Six 12V bilge pumps are attached to the frame, which provide the thrust for the ROV after being modified and carefully chosen propellers were fixed to each motor shaft.

In order to carry out the tasks needed, the team has chosen to proceed with the "simple but effective option" in order to minimise potential faults which may occur, with a simple tooling on the underside of the ROV designed to turn and open a hatch and an electro-magnetically operated manipulator to transport the airline. The ROV is operated by a surface control system which links to the underwater unit via a tether and two wide-pan underwater cameras are used to view all progress during tasks.

II. Team Structure:



Slimane
Team & Mission Leader



Chris
Co-pilot

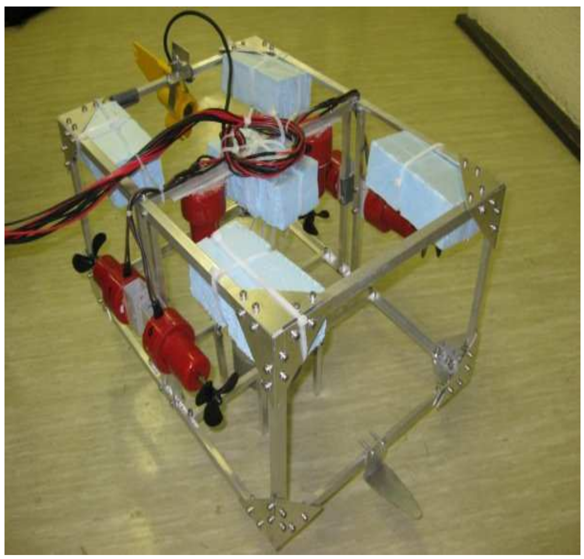
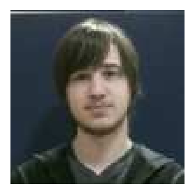


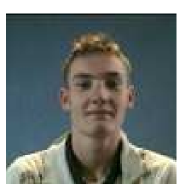
Figure 1: Uncompleted ROV

Sakshi
Pilot

Tom
Tether manager
&
ROV launcher



Jack
Tether manager
&
ROV launcher



Barry
Technical
assistance

III. Design rational:

The ROV was designed in order to carry out the competition tasks in a simplest and effective way, hence the design process started first by identifying all the possible approaches to perform the tasks, and then the optimal ideas were discussed within the team to end up with an ideal solution.

The frame of the ROV has a flexible rectangular shape of 300X250X500mm (see figure 1), it is mainly made of an aluminium angle bar of ½ inch width and 3mm thickness which provides the strength to the vehicle, in addition it minimises the drag force exerted on the ROV while it is moving under water. The angle bars are joined together using triangle brackets of 1mm thickness, and this last are fixed to the bars using M3 screws. Aluminium square bars of 10X10mm were also used to reinforce the frame and attach the thrusters and the tooling to the ROV.

The thrusters used in this ROV are the modified Bilge Pump of 1100 GPH which operates at 12Vdc, and the propeller used has three blades with a diameter of 65mm to maximise the thrust provided by the motors (see figure)

Figure 2: Thrusters

For the buoyancy, ordinary foam was mounted on the ROV to have neutral buoyancy which helps carrying the tasks in an efficient way.

The developments of payloads to perform each mission tasks are illustrated as following:

- ***Task 1:***

The first of the tasks at hand for the ROV is to survey a damaged submarine. For the observation of the submarine, two onboard black and white cameras were fitted and bolted on the top middle bar of the ROV; one is facing the front of the ROV to survey the damage, and the other is facing down to give a clear view of the prongs and transfer skirt.

- ***Task 2:***

The second task involves rotating a hand wheel 360 degrees to open a hatch and access a transfer pod.
In favour of creating a system whereby an onboard rotating mechanism could move the hand wheel, it was decided that it would be optimal to take advantage of the ROV's manoeuvrability. To do this, four prongs were positioned underside of the vehicle. These were designed to correspond with one of the four cross bars and push against them as the ROV uses its own thrusters to spin on the spot 360 degrees.

The team decided to place as much tooling on the central underside as possible for balancing the ROV and maximise the visibility. As a result, prongs and the transfer skirt (see task four) would be situated in very close proximity. For this, an adaptation of the prongs was required.

The concept to create telescopic prongs would alleviate the issues resulting in overlapping tooling which would ordinarily occur. The prongs would now be situated on the outside of the circular skirt. Each prong would be constructed from a solid square length of aluminium which would slip inside a larger hollow segment. A channel was cut into the side of the hollow portion so that a bolt could be placed through the solid part (see Figure 3). This would mean that the solid portion (piece has a contact with the hand wheel) would hang under its own weight in ordinary use, however when the vehicle is required to mate the transfer skirt, these sections will be pushed up onboard so as not to obstruct the access.
For the next part of the challenge a transfer pod is to be moved and inserted into the escape tower. To do this the team decided to again make use of the vehicles mobility and fix a hook onto the bottom bar of the front side of the vehicle.

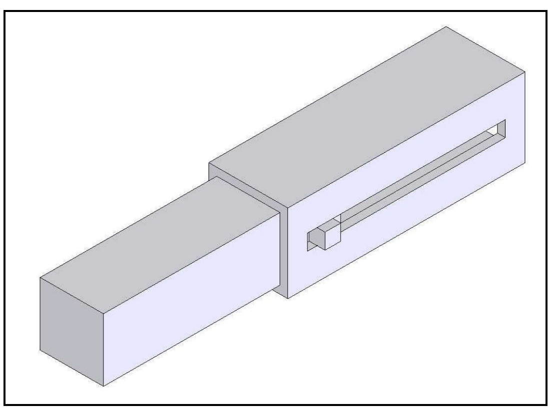


Figure 3: telescopic prongs

- ***Task 3:***

The third task involves transporting the airline to the submarine to provide ventilation. To do so, 12Vdc electromagnet of 25mm diameter is placed at the front side of the ROV which make an angle of 45 degrees with the horizontal, and it is used to attract the metal sheet that holds the airline using the clips which are fixed on the sheet. (See figure 4)

Figure 4: Electromagnet

- ***Task 4:***

For Challenge Four the vehicle was required to mate a transfer skirt with an escape hatch. This was created from 110mm PVC pipe. This was capped at one end with a piece of transparent Perspex having several holes drilled into it. This transparency would enable a greater visibility, and hence ease, for the tooling camera when docking is required. The holes in the Perspex also mean that the skirt would not capture any air which would affect the buoyancy and the balance of the vehicle.

IV. Control system:

- ***Introduction***

The initial plan for the control system was to have a MOSFET based H bridge circuit for the motor driver circuits. This would allow the speed of the motor to be controlled. The turning on/off and direction control of each motor would be controlled by a microcontroller. This would be programmed in C. In order to interface the control system with the ROV pilot, joysticks were going to be used. The analogue to digital port on the microcontroller would be utilised here to convert the position of the joystick into a binary representation of the speed which would then be used to determine direction/speed of each motor.

The system block diagram below represents this initial idea:

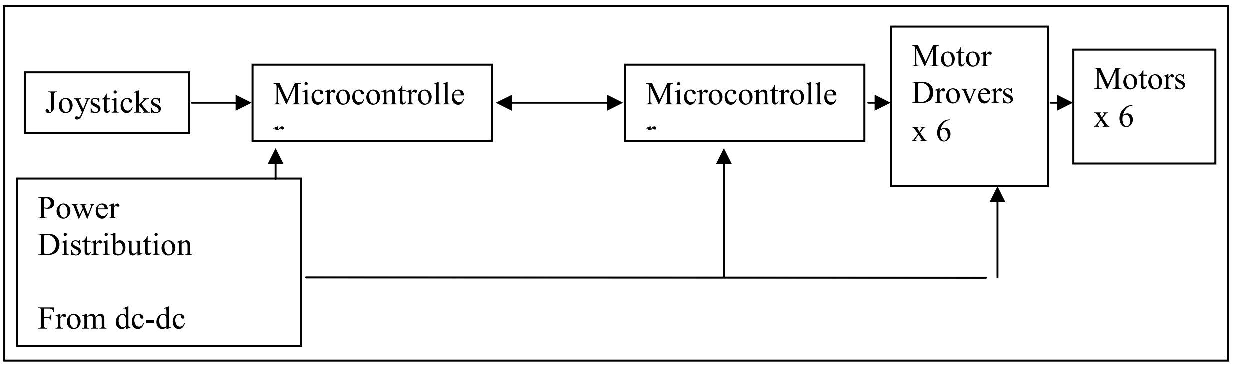


Figure 5: Initial Control System.

Within the team there was not much experience with programming or electronics and time restraints meant completing the initial plan was unrealistic.

- ***Back up plan***

The back up plan for the electronics was to use switches to simply turn the motors on and off. Protection diodes would be placed across the motor terminals to protect against back emf. The motors would be positioned in such a way so that a direction change of the motors is not necessary. The only motor that would be required to be reversed was the up/down motor. A double pole double throw relay would be used to reverse the direction of the motor.

The vertical thrusters are connected in parallel. Initially a relay turns the vertical thrusters on or off, then a second relay switches the power connections to the motor terminals so that the direction can be reversed. All the relay coils have protection diodes across them in order to protect against back emf. It should be noted that all the motors have an LED in parallel with them and in the case of the bidirectional motors a bidirectional LED is used. Appropriate current limiting resistors are used in series with these LEDs. The purpose of the LED's is for testing and troubleshooting purposes to see whether a motor is on or off and in what direction. (Note this is not included in the illustration below for clarity)

Below is an illustration of the system.

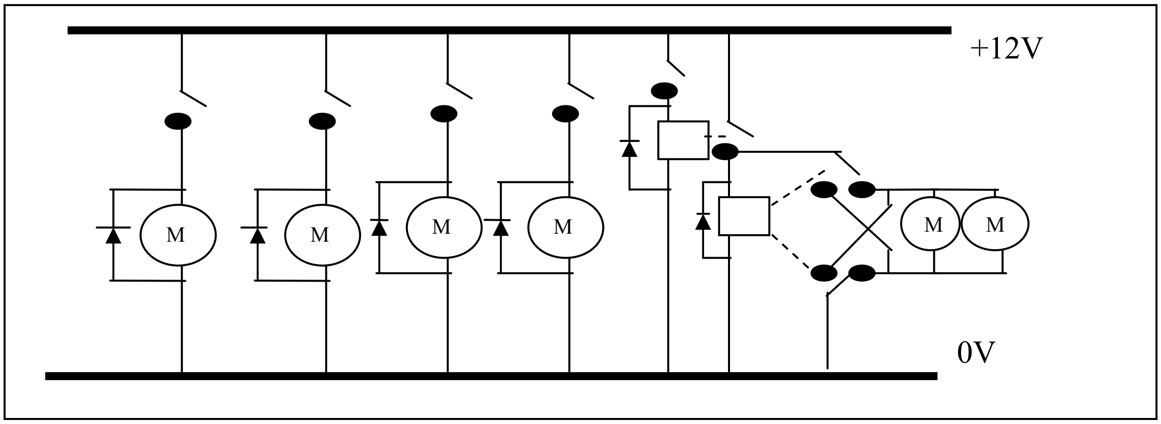


Figure 6: ROV Controlling System

The electronics would be on the topside. This has worked out very well as it leaves a very open frame in the pool and the view from the camera is very clear and unobstructed. It does have the disadvantage that the tether is quite large in diameter as it is required to have a positive and ground line for each motor. This problem was improved slightly by carefully selecting the type of wire used, taking into consideration ratings and diameter.

The above circuit was realized on a printed circuit board, with push down terminal blocks to make the connection to the power supply and the motors. This PCB would be mounted in the control box so that the PCB mountable switches used would protrude from the box allowing access to them.

The system block diagram for this can be seen below.

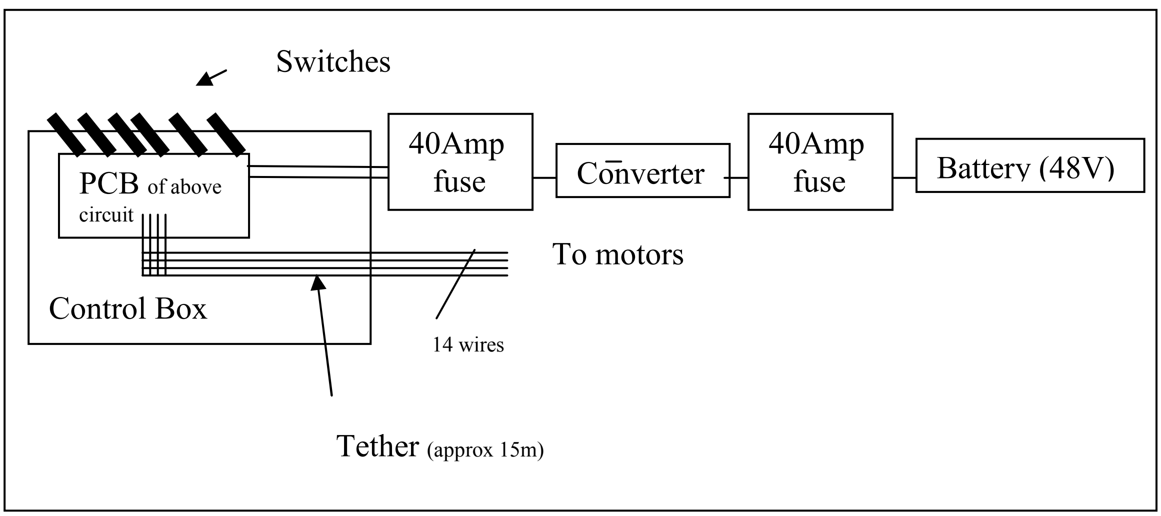


Figure 7: ROV Controlling System Diagram

- ***Power supply***

The power supply required for the ROV is 12V and only 48V is available. A dc-dc converter was sourced that was capable of supplying all 6 motors at 12 V, hence 500W output would ensure suitable operation. Due to the large heat dissipation, the converter has a built in cooling fan. Another important feature of this converter is the ability to adjust the output voltage between 11 and 15V. This allows for the volt drop down the tether to be compensated for.

Figure 8: Dc-Dc Converter

Source: Sunpower UK Ltd

- ***Safety:***

To protect the ROV from the current excess which can cause failure, one fuse of 40 Amps was placed between the battery and the converter, and another one between the converter and the control box of the ROV.

V. Budget / Expense sheet:

06-Mar-09	Alum Square 3/8" (1m)	4	Used For Struts on the Chasis of ROV and tooling	Budget	2.78	11.12
08-Mar-09	Delivery of Aluminium	1	Delivered through aalco	Budget	10.00	10.00
12-Mar-09	Centre off Standard r/a toggle switch, 2A	7	For Control Box	Budget	3.04	21.28
12-Mar-09	100m Black Tri Rated Cable 0.5mmsq	1	For Tether	Budget	5.00	5.00
12-Mar-09	100m Red Tri Rate Cable 0.5mmsq	1	For Tether	Budget	5.34	5.34
12-Mar-09	Water Proof Heatshrink	20	For waterproofing connections	Budget	0.59	11.80
12-Mar-09	Acetoxy Silicone Sealant, 310ml	2	For Sealant	Budget	5.44	10.88
12-Mar-09	A2 s/steel hex socket cap screw M4x16mm	3	Bags of 50	Budget	8.40	25.20
12-Mar-09	A2 s/steel self locking nut M4	2	Bags of 100	Budget	8.74	17.48
12-Mar-09	A2 s/steel plain washer M4	1	Bags of 250	Budget	3.19	3.19
16-Mar-09	Rull Mate 1100GPH Bilge Pump	9	Thrusters Plus Spares	Donation from RGU	60.00	0.00
16-Mar-09	3 Bladed Props.	9	Propellers for Pumps	Donation from RGU	1.00	0.00
18-Mar-09	Sqm sheet of alluminium, 1mm thick	1	For Bracing Cassis, increase stability, and for tooling	Donation from RGU	3.50	0.00
20-Mar-09	Mapli Underwater CameraKit	2	For Camera on the ROV	Budget	79.99	159.98
24-Mar-09	Bouyancy Foam, 700x500x300	1	Bouyancy	Donation from RGU	18.00	0.00
28-Mar-09	PCB plus Components inc. Fuse	1	Controller Board	Donation from RGU and Barry Mitchell	0.00	0.00
28-Mar-09	Perspex Topped Box	1	To Be the Control Box	Donation from RGU	8.00	0.00
28-Mar-09	Perspex Pipe, 12mm Diameter	1	Transfer Skirt, Constructed from Offcuts	Donation from RGU (Salvaged)	0.00	0.00
25-May-09	Holding electro magnet,25mm dia 12Vdc	1	For Tooling, 130N Holding Force	Budget	25.79	25.79
					Total Expense:	470.06

VI. Challenges:

This year, all the members joined the ROV team were new to the field, and this led to face different challenges. The main challenge was that of the members who left the team in the middle of the term because of their worries about consequences of the project on their academic performance. As a result, another challenge arose, which was a lack of the team expertise on robotics, programming…etc.

As the team members were mainly from a mechanical course, the best approach chosen to overcome the challenges was to design an ROV in a simplest form with a minimum use of electronics, and this can be shown from the idea of using telescopic prongs which work without need of electronics. In addition, the use of switch control is the basic form on how the thrusters can be condoled.

VII. Troubleshooting:

During the process of constructing the ROV to the specifications of the design, problems arose and each one was tackled appropriately and solved. The main problem was electronics, exactly considering the software which was intended to be used.

Originally the ROV was designed to have a vector thrust with a speed control system controlled using a joystick; however the lack of the team expertise on programming complicated the idea.

Different approaches were discussed within the team during the design about the ROV controlling system, for example: using a game console controller (x-box or play-station), and the use of basic boxes with flick switches, analogue controls, variable resistors wired up and official joy sticks with thrust capacity such as ones used in flight simulation packages. All ideas were taken as useful and decided that a joystick would be suitable. However, after the team was informed that the programming code and software was more complicated, the team decided to change to a much simpler form of control.

As a result of a time constraints and the lack of team expertise, a simple approach of switching on and off the motors were used to control each thrusters individually, which in turn led to reposition the thrusters to ease the control of the ROV using the switch control box.

The main technique used was that of discussion, a good communication between the team members was necessary for solving this problem as it affected every member of the team area of work. The electronics, design and construction had to be rethought so as the ROV would perform at the required output and complete the tasks. Eventually, the problem itself was resolved and the ROV continues to perform at a high standard.

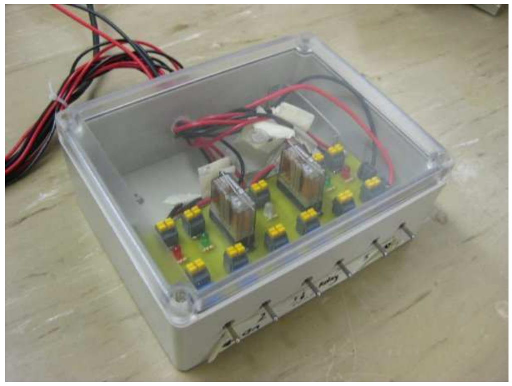


Figure 9: Controlling Box

VIII. Future improvements:

There are several improvements that could be made to the current control system. One would be to replace the system with the initially intended design; however the current control system can be improved.

The switches chosen are not spring loaded toggle switches and therefore manual effort to turn them off is required. If they were spring loaded it would improve the ROV pilots control. The switches used were also PCB mountable. In order to securely fix the switches to the control box, non PCB mountable switches should be used.

Although the switches were arranged in an order to help the pilot use the controller, it would be much more appropriate if there was a single switch for manoeuvring forward and backward, and another switch for turning.

It may be advantageous to use relays to control all motors. That way the electronics could be placed on the ROV and only control signals to the coils would be required in the tether and as a result its overall diameter could be reduced. This has the disadvantage that some electronic housing would be required on the ROV which would reduce the openness of the design impairing visibility.

In order to reduce the diameter of the tether there are a couple of options. One option would be to have a single ground wire running the length of the tether and for all motor connections to ground to be done on the ROV.

IX. Lesson learned or skills gained:

The competition tasks for 2009 required a purely innovative ROV that would ideally be versatile in accommodating all the tasks. To design such a machine projected the need to learn new skills such as:

- Implementing ideas in an understandable fashion so that all team members were clear in understanding
- The use of various different machines in order to manufacture different components of the ROV
- Learning how to successfully programme a circuit board.

One of the lessons we learned as a team was the necessity of productively deploying our time to various parts of the ROV. Although our team only compromises of six members making it a relatively small team as compared to others, we still assigned members to various parts of the ROV to make the whole designing process more efficient. Three members were assigned to electronics, two to the manufacturing of the ROV chassis and one to the tooling designing. However, near the end of the process, we soon realised that we were all lending a hand to every other part of the ROV in an effort to complete it for the initial Regional Competition. Although this initiated in a few improvements to different components, it also meant that some parts were not completed to optimum capability. This problem was duly tackled in preparation for the MATE ROV competition in Massachusetts. We drew a list of all the improvements/changes to be concurred on our ROV and each member was assigned up to two tasks each from the list which they then had to carry out and report back to the team leader in due course, ensuring that all aspects were tackled in a more organised manner.

X. Reflections:

"I have always liked working in team projects and joining the ROV team at the Robert Gordon University offered a chance to gain more experience in that field. Building a piece of active machinery from scratch is an achievement on its own and as a Mechanical Engineer student; I gained valuable insight into the amount of innovation and creativity that can be required for such projects.

Although as a team we faced a few challenges such as time management and sometimes the lack of communication, it was rewarding to see our ROV successfully complete the initial task to open the escape tower hatch, at the Regional Competition in Scotland. Our design was a simple straightforward idea to minimise any confusions, however, still comprised of many different parts and I found it interesting to see how all these parts all pieced together. The amount of time and dedication required to engineer such a project is also amazing. We started the project during our second semester at university and soon found it hard to find enough time to properly work on the project and time was also lost on lack of focus on what we were targeting to complete. However, the team itself came together when nearing the deadline and pulled through to complete the project with good morale. And although there is room for a certain degree of improvement: that is the case with most things. Working on this project helped to advance my team working skills and I learned new skills which greatly enhanced my experience as a whole."

- Sakshi Sircar -

XI. Description of a submarine rescue system:

With the majority of the world's submarines operating in substantial depths, the concept of a submarine rescue is daunting and provides a significant challenge to those responsible. The basic principle of the rescue methods employed today involves a small rescue vessel diving to, and mating with the rescue hatch of the submarine. From here the craft would 'ferry' the passengers of the distressed submarine to the surface.

The first system developed for submarine rescue was the McCann Submarine Rescue Chamber, developed in 1928 after a series of US Naval submarine tragedies.

Figure 10: McCann Submarine Rescue Chamber

Source: http://dbal.co.uk/images/rescue/rescue02-large.jpg

As shown in the image above, the McCann rescue Bell was a pear shaped chamber, which could be lowered down from a mother ship on the surface. This design had a number of successful applications such as the rescue operation for the SS-192 Squalus on 23 May 1939. However it was soon acknowledged that the design had several flaws particularly in conditions involving strong currents and in depths exceeding 850 feet[1].

Having over come many of these issues, the craft in use by the British Royal Navy currently is the NATO developed, manned submersible LR5. This has a rated rescue depth of 400m however has made successful mates at 600m.
As this system is equipped with thrusters it is able to accurately navigate its way to the escape hatch, unlike the McCann Bell which relied on still seas to fall vertically. It also has sonar and several cameras around the vessel for observation of the sunken submarine.
The characteristics developed and outlined above are all present on the RGU ROV. Being highly manoeuvrable and possessing clear visibility below will allow the craft to accurately position the transfer skirt where necessary[2].

XII. References:

[1] - John P. *Submarine Rescue Chamber (SRC) / McCann Bell*. [home page on the internet]. GlobalSecurity.org; c.200-2009. Available from: http://www.globalsecurity.org/military/systems/ship/systems/src.htm [accessed 27/05/2009]

[2] - Rumic Ltd. *Manned Submersible LR5 Specification.* [home page on the internet]. Jane's Information Group, 2009. available from: http://www.janes.com/defence/naval_forces/news/jut/jut000816_1_n.shtml [Accessed 27/05/2009]

XIII. Acknowledgements:

We would like to thank the following sponsors for supporting the RGU team:

- **The Robert Gordon University**, Aberdeen, United kingdom
- **BP (British Petroleum),** Principal Sponsor.
- **Acergy,** Major Sponsor.
- **MATE (Marine Advanced Technology Education Centre)**
- **OPITO (The oil & gas academy),** Sponsor.
- **Nylacast,** Sponsor.
- **SMD,** Sponsor.
- **Subsea UK,** Sponsor.
- **Tritech,** Sponsor.
- **Triton Group,** Sponsor.

We would like to thank also the university development researcher Mr Craig Rutherford and development manager Rhada Thomas for organising events and the trip to America.